

## DS&G – UPCUTZ Aquifer versus Aquitard

At the request of the DS&G Trust, Golder reviewed readily available hydrogeologic reports to evaluate if the Upper Potomac Confining Unit Transition Zone (UPCUTZ) would be considered an aquifer or an aquitard facies within the context of the regional hydrogeologic framework. The distinction between aquifer and aquitard is significant to development of cleanup goals for the UPCUTZ and the Upper Potomac Aquifer (UPA) because the UPA is used regionally as a source of drinking water.

The following presents a summary of regional geologic and hydrogeologic descriptions for the Potomac Formation, followed by a comparison of regional descriptions and aquifer test data to data from the DS&G Site.

### **REGIONAL GEOLOGIC DESCRIPTIONS**

Based on a review of the information presented in the Delaware Geologic Society, Open File Report 45 titled “Characterization of the Potomac Aquifer, an extremely heterogeneous fluvial system in the Atlantic Coastal Plain of Delaware” by McKenna et al in 2004, the aquifer and aquitard units, collectively referred to as the “Potomac Formation” beneath the DS&G Site area are interpreted to be comprised of mottled silts and clays (weathered floodplain paleosols, UPCU) which form aquitards, and thick sands (isolated channels) which form the aquifer unit (UPA). Between these two is a facies that includes interlaminated sand and silt (distal levee/flood plain) which forms the UPCUTZ. The following provides the sedimentological and aquifer/aquitard characteristics of these units as stated by McKenna et al. (2004), we have included them as observed from top to bottom of the stratigraphic column (Potomac Formation) for the DS&G site, and the unit name used by Golder at the DS&G Site (not used in McKenna et al. (2004)) is provided in bold-type face:

#### **Upper Potomac Confining Unit (UPCU) - Mottled Silts and Clays Facies:**

##### *Sedimentological characteristics -*

- Predominantly variegated silts and clays, light gray, olive-tan, red, orange, purple or whitish grey
- Sandy lithologies commonly contain a significant component of silt or clay
- Exhibits extensive mottling or irregular banding
- Contains sphaerosiderite

##### *Aquifer/aquitard characteristics -*

- Important aquitards across the study area (and perhaps regionally)
- Dense clays and hard paleosols are not fractured and have very low permeability
- Interbedded thin sands and silts may allow some leakage across aquitards

#### **UPCU Transition Zone – Interlaminated Sand and Silt (Distal Levee/Flood Plain) Facies:**

##### *Sedimentological characteristics -*

- Centimeter-scale beds and thinner laminae
- Includes sandy silt, silty sand, and silty clay, fines predominate
- Current ripples evident in some thin sand beds
- Often associated with abundant charcoal, mud clasts in places

*Aquifer/aquitard characteristics -*

- Sands may have broad lateral extent on flood plain, but thin-bedded character makes continuity difficult to establish
- Most sands are silty and less permeable, not aquifer quality
- Silts and clays within and enclosing this facies are aquitards across parts of the study area

**Upper Potomac Aquifer (UPA) - Thick Sand (isolated channels) Facies:**

*Sedimentological characteristics -*

- Individual sands 5-20 ft thick
- Occur within 10-30-ft-thick fining upward packages
- Sands fine upward from fine to medium (less commonly coarse to very coarse) sand to silty very fine sand, fines above are preserved
- Sedimentary structures are uncommon, most commonly cross-bedding
- Mud chips and scattered charcoal may occur

*Aquifer/aquitard characteristics -*

- Deposition in isolated channels yields poor lateral continuity
- Clean fine and medium sands have good porosity and permeability
- Commonly fine upward into silts and clays which may form aquitards

(McKenna et al., 2004)

**REGIONAL AND SITE-SPECIFIC AQUIFER TEST DATA**

Based on aquifer tests performed in the area, McKenna et al. (2004) indicated that aquifers represented by isolated channels have horizontal hydraulic conductivity values of 3 to 300 feet per day (see diagram below). This is similar to the horizontal hydraulic conductivity of the UPA at the DS&G site which is between 50 and 70 feet per day.

As shown in the diagram below, McKenna et al. (2004) indicated that based on the same testing, the aquitards represented by the weathered flood plain with paleosols (mottled silts and clays) and the interlaminated sand and silt (distal levee/flood plain) facies have a vertical hydraulic conductivity of  $10^{-3}$  to 3 feet per day. While the vertical hydraulic conductivity of the UPCUTZ (which represents the generally fining upward sequence between the UPA and UPCU) has not been evaluated at the Site, slug test data for the UPCUTZ (see below) at the DS&G site indicate a horizontal hydraulic conductivity of about 0.7 to 9 feet per day. Due to the preference for horizontal migration in the UPCUTZ as discussed in the Supplemental Site Characterization-Revision 1 report (Golder, 2014), the horizontal hydraulic conductivity is anticipated to be much greater than the vertical hydraulic conductivity ( $K_h \gg K_v$ ) within the UPCUTZ (i.e., greater than the standard 10:1 ratio). Applying a conservatively low 10:1 ratio of horizontal to vertical conductivity for this unit, produces a vertical hydraulic conductivity of 0.07 to 0.9 feet per day. This value is lower than the range for aquifer materials indicated by McKenna et al. and within the range for the aquitard materials indicated by McKenna et al. As such, the UPCUTZ materials are representative of aquitard materials, and should not be considered aquifer (UPA) materials. Furthermore, the contrast between the horizontal hydraulic conductivity values for the UPA (approximately 50 to 70 feet per day) and the UPCUTZ (approximately 0.7 to 9 feet per day) indicate that groundwater will flow preferentially within the UPA to extraction wells and that UPCUTZ groundwater will not be a significant contributor to the UPA groundwater.

In addition, Freeze and Cherry (1979) define an aquitard as “the less-permeable beds in a stratigraphic sequence. These beds may be permeable enough to transmit water in quantities that are significant in the study of regional groundwater flow, but their permeability is not sufficient to allow the completion of production wells within them”. This definition of aquitard has been used for vertical delineation of aquitards and aquifers elsewhere in Delaware (Andres and Klingbeil, 2006).

## CONCLUSION

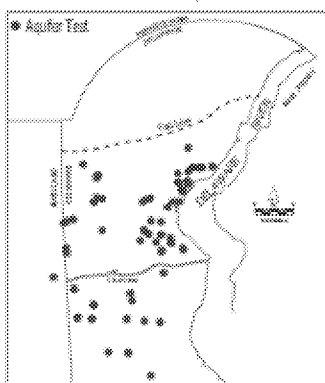
In summary, the Potomac Formation is comprised of aquifers and aquitards, and the UPCUTZ represents a portion of an aquitard unit within the Potomac Formation. The UPCUTZ should be handled as an aquitard for the following reasons:

- conductivity contrast between the UPCUTZ and UPA
- significantly less permeable facies than the UPA in the Potomac stratigraphic sequence
- UPCUTZ is thinner (generally 10 to 15 feet thick) and less conductive (generally 0.7 to 9 feet per day) relative to the UPA (generally 30 to 60 feet thick, 3 to 300 feet per day); therefore, extraction wells installed in the UPCUTZ would not be productive, and the UPA is the preferable unit in terms of groundwater extraction
- publications by the State of Delaware as referenced herein indicate the facies referred to as the UPCUTZ at the DS&G site is representative of an aquitard unit

As such, it is Golder’s opinion that the UPCUTZ is an aquitard unit (or a portion of the aquitard unit that includes the overlying UPCU). Furthermore, Site-specific preliminary remediation goals for the proposed area of attainment (see Memo on Preliminary Cleanup Goals, Golder (2014)) should not be developed using data from wells screened in the UPCUTZ, and cleanup goals for the UPCUTZ should not be equal to those established for the UPA, because the UPCUTZ is not an aquifer unit. Instead, UPCUTZ cleanup goals should be based on fate and transport modeling that accounts for the degree of dilution/attenuation that occurs when limited volumetric flux from the low-transmissivity UPCUTZ aquitard unit mixes with the much larger volumetric flux of the high-transmissivity UPA.

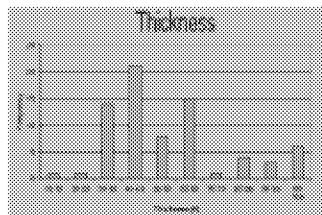
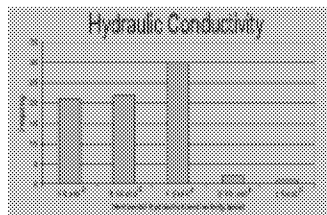
Excerpts from McKenna et al., 2004, Sheet 3:

### Locations of Aquifer Tests



### Aquifers

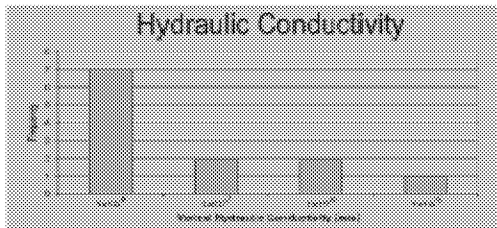
#### Stacked Amalgamated and Isolated Channels



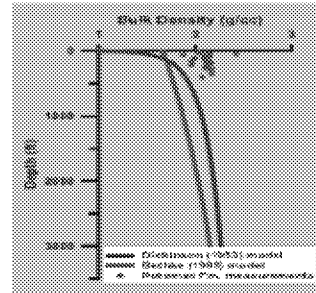
Horizontal Hydraulic Conductivity =  $10^{-4}$  -  $10^{-4}$  m/s (3 - 300 ft/day)  
 Transmissivity = 4 - 1800 m/day (40 - 20,000 ft/day)  
 Storativity =  $10^{-4}$  -  $10^{-5}$   
 Thickness = 3 - 30 m (10 - 100 ft)

# Aquitards

## Distal Levee / Flood Plain, Weathered Flood Plain with Paleosols



Vertical Hydraulic Conductivity from tests  
=  $10^{-8}$  -  $10^{-5}$  m/s ( $10^{-3}$  - 3 ft/day)  
Highly variable (over 3 orders of  
magnitude range from 1 test at 3  
different wells)



Mudrocks containing paleosols are  
overcompacted and are estimated to  
have very low local permeability  
( $10^{-15}$  -  $10^{-12}$  m/s;  $10^{-10}$  -  $10^{-7}$  ft/day)

### Golder's UPCUTZ Slug Test Data from SSC Rev 1 (2014):

				Calculated Hydraulic Conductivity (K) Values					
Well ID	Screened Interval ft bgs	Test Type	Test Date	Hvorslev		Bouwer-Rice		Geometric Mean	
				cm/sec	ft/day	cm/sec	ft/day	cm/sec	ft/day
DDA-06 (TZ)	48-56	Falling Head	4/10/2013	4.41E-05	1.25E-01	4.38E-05	1.24E-01	4.4E-05	1.2E-01
		Rising Head	4/10/2013	5.88E-05	1.81E-01	6.27E-05	1.78E-01	6.0E-05	1.7E-01
DDA-07-TZ	44-49	Falling Head	4/11/2013	2.83E-04	7.45E-01	2.48E-04	7.04E-01	2.6E-04	7.2E-01
		Rising Head	4/11/2013	1.87E-04	5.31E-01	2.51E-04	7.11E-01	2.2E-04	6.1E-01
DDA-08-TZ	48-59	Falling Head	4/11/2013	8.77E-05	2.49E-01	8.73E-05	2.49E-01	8.7E-05	2.5E-01
		Rising Head	4/11/2013	1.13E-04	3.20E-01	1.03E-04	2.92E-01	1.1E-04	3.1E-01
DDA-12-TZ	39-54	Falling Head	4/10/2013	NA	NA	NA	NA	NA	NA
		Rising Head	4/10/2013	4.01E-03	1.14E+01	2.76E-03	7.83E+00	3.3E-03	9.4E+00
DDA-14-TZ	48-59	Falling Head	4/11/2013	2.42E-04	6.85E-01	2.32E-04	6.59E-01	2.4E-04	6.7E-01
		Rising Head	4/11/2013	1.88E-04	5.28E-01	2.01E-04	5.70E-01	1.8E-04	5.5E-01
DDA-15-TZ	54-64	Falling Head	4/11/2013	1.78E-03	5.07E+00	1.76E-03	4.98E+00	1.8E-03	5.0E+00
		Rising Head	4/11/2013	1.78E-03	5.05E+00	1.48E-03	4.21E+00	1.6E-03	4.6E+00
DDA-16-TZ	51-59	Falling Head	4/10/2013	6.26E-04	1.77E+00	5.70E-04	1.62E+00	6.0E-04	1.7E+00
		Rising Head	4/10/2013	7.59E-04	2.15E+00	7.19E-04	2.04E+00	7.4E-04	2.1E+00
						Geometric Mean		3.1E-04	8.8E-01

Note: